



ANALYSIS OF GRANULARITY WITHIN GENERATIVE LEARNING OBJECTS TO SUPPORT REUSABILITY

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Abstract

Reusability of the learning objects (LOs) and its usefulness is the main engine for the LOs theory development in the e-learning domain. We discuss the granularity problems which are directly related with LO reusability in the context of using generative learning objects (GLOs). The main problem is to select an appropriate LO granularity degree without losing the possibilities of LOs reusability. Naturally, the smaller the LO and the more unrelated it is to a specific context the more reusable it is in various contexts. However, decomposing LO to separate elements and eliminating the context we lose the LO pedagogic value, i.e. such LOs become non-efficient with respect to the learner. Therefore, to solve the problem, we suggest creating GLOs combining two technological paradigms: feature diagrams (FDs) for GLO specification in the early development phase and generative techniques for GLO implementation. The chosen paradigms ensure the evaluation of the possibilities of reusability in the early GLO development phase (it means, we have a possibility to evaluate the efficiency of the composed GLO) and the generative reuse. GLO enables the user to select the requested parameters from the meta-interface on which a specific LO item, meeting the requirements of the user, is generated. By specifying with GLO feature diagrams we may foresee possible GLO contexts, filling GLOs with versatile information of a particular field. Thus the GLO becomes pedagogically efficient, adaptive and its granularity degree does not restrict the possibilities of reusability. Therefore, we may draw a conclusion that composing a GLO we automatically partially solve the existing problem as the GLO granularity does not restrict the possibilities of reusability. However, we must know how to evaluate the GLO granularity degree because while describing the GLO by means of meta-data it is necessary to indicate the aggregation level. To solve the problem we suggest using a formal graph-based model which not only enables the creation of learning scenarios from the generated LO items but also allows the evaluation of the granularity degree.

KEYWORDS: learning objects, generative learning objects, reuse, granularity

Introduction

Though learning objects (LOs) are known in e-learning for over 15 years, there is no a unified definition of the term so far. In the context of this paper, we accept the following definition of the term: LO is a small, stand-alone, mediated content “chunk” that can be reused in multiple instructional contexts, serving as building blocks to develop higher-level compounds (e.g. lessons, modules, etc.) (Wiley 2000; Wiley 2002; Nugent, Soh and Samal 2006). Two interrelated aspects follow from this definition: reusability and compositionality. Other papers (Polsani 2003; Ally 2004; Morales, García and Barrón 2005; Leeder, Davies and Hall 2005) also consider reusability as one of the most important properties of LOs.

Currently LOs are seen as a connector of the learning and technology infrastructure. That explains why LOs are discussed worldwide from various perspectives; for example, the requirements for the learning objects’ composition and their advantages to learners and developers/instructors, influencing the learning efficiency, are at the focus of researchers. The need for composing LOs is due to the possibilities they can provide (Metros and Bennet 2002; de Salas and Ellis 2006).

Reusability of LOs is indeed attractive; it can be seen as a strategy to enhance quality, faster development times, lower development costs, productivity, efficiency,

reliability, etc. (Paris 2003; Krämer 2005). In the field of LOs, however, there is no a single and unambiguous understanding of reusability as compared to the field software engineering. The scientific literature gives a wide range of theoretical assumptions on reusability of LOs; however, we lack a practical guidance and samples of a specific realization, which would ensure greater reusability of LOs. Thus we can assume that reusability of LOs is still an objective, a nice vision, and real implementation in practice is rather slow (Currier and Campbell 2002; Paris 2003; Krämer 2005). Moreover, the impact of reusability is directly linked to the following properties of LOs: granularity and aggregation (also called as compositionality). How should an appropriate LO granularity be selected, and how many learning objects should be composed into a particular block (e.g. a lesson, course, etc.) so as to ensure the reusability? As granularity has a direct impact on reusability, this problem should be at the focus of course designers. First of all, in order to ensure reusability, a LO must be designed with this purpose in mind from the very beginning of the development life-cycle (Mohan and Bucarey 2005), i.e., reusability should be intended in the LOs specification.

In such a context, we need to evaluate granularity at a high abstraction level, for example, at the specification level. The aim of the paper is twofold: first to analyze reusability of LOs with granularity in mind, and second to show how to aggregate LO instances with the help of a

graphs-based model in the context of using generative reuse, i.e., generative learning objects (GLOs) (Boyle, Leeder and Chase 2004; Morales, Leeder and Boyle 2005).

We proposed to use Feature Diagrams (FDs) as a graphical language for the feature-based conceptual modelling and for the specification of granularity of the learning content at a higher abstraction level (note that originally FDs were introduced in Feature-Oriented Domain Analysis (FODA) method (Kang *et al.* 1990) and now are widely exploited in software engineering). Then, we propose to use generative technologies to create a GLO, from which LO instances can be generated automatically on demand. And finally, when we already have LO instances, we can use formal graph-based model to model a composition of LO instances (i.e. to model learning content) and according to the created graph, we can evaluate the LOs granularity degree and aggregation level.

The structure of the paper is as follows. The next chapter provides the analysis and evaluation of LOs granularity. Then we introduce generative learning objects (GLOs) and what technologies we offer to use in their development. And finally we analyze and identify GLOs granularity according to proposed graph-based model.

Analysis and evaluation of LOs granularity

LO granularity refers to the degree or detail or precision contained in a learning object, as well as its size, decomposability and potential reuse (Koohang and Harman 2007). Different researches consider different levels of granularity, called the aggregation level (according to LOM standard). LO definitions are non-

concrete and usually allow for an extremely wide variety of granularities. Therefore, seeking for a more precise and correct LOs granularity analysis, we have chosen different research objects related to LOs: LOs standards, content models, separate research groups. Though various authors differentiate between the number of levels (from 2 to 5), all the levels can be ascribed to one of the three levels of aggregation: smaller elements, which comprise LOs, the learning objects themselves, and aggregated LOs (Table 1). We will follow the latter attitude while speaking about LOs granularity and its aggregation levels.

Analysis the aforementioned levels from the perspective of reusability shows that the elements of the first level of aggregation may be reused without any modification. According to Wiley (2003), the smaller the LO element is, the bigger the potential of reusability it has. Passing to other levels of aggregation, the possibilities of reusability reduce. Naturally, an LO composed from particular elements (texts, pictures, audio or video fragments) cannot be appropriate to any context and cannot ensure such high efficiency of reusability as a separate elements. In this respect, when increasing the potential of LO reusability, authors (Currier and Campbell 2002; Wiley 2003; Parrish 2004) suggest refusing the LO context, i.e. they say, that LO should contain as a little context as possible. But here we face the major contradiction (Boyle, Leeder and Chase 2004): on the one hand, it is assumed that the potential of LO reusability is increasing alongside the greater degree of independence from the context, and on the other hand, educators assert that a context is the main component of an effective learning process. After all, increasing the possibility of reusability we should keep in mind the LO audience (students, who are the target audience of LO).

Table 1. LO granularity and aggregation levels

Aggregation level	SCORM (2004) (standard)	LOM (2002) (standard)	Barrit <i>et al</i> (1999) (RLO/RIO model)	Wagner (2002) (Learnativity content model)	L’Allier (1997) (NETg LO model)	Eduworks corporation
LO components	Assets (image, audio, text, etc.)	Raw media data or fragments	RIO (Concept, Fact, Process, Principles or Procedures)	Raw Media Elements (paragraph, illustration, animation, etc.)	—	Content fragments
				Information Objects (set of raw media elements)		Information objects
LO	Sharable Content Objects (SCO) (collection of one or more assets + independent for improving reusability)	Learning objects (collection of level 1)	RLO (collection of 7+-2 RIO, plus an overview, summary and assessment)	Learning objects (based on single objective)	Topic (independent learning objects that contain a single learning objective and have corresponding activity and assessment)	Learning object
Aggregated LO	Content Aggregation (course, module, chapter...)	A collection of LO (e.g. a course)	—	Aggregate Assembles (lessons)	Lesson	Learning component
		A set of courses		Collections (courses, stories)	Unit	Learning environment
					Course	

Thus, a LOs must be pedagogically “enriched”, efficient, valuable, based on the created learning theories (Boyle 2003; Salas and Ellis 2006). Naturally, the richer the context of LO is, the easier it is for the learner to benefit from it. For example, if a student finds the Dijkstra’s algorithm in the LOs repository without any context and specific samples of application, it is unlikely that the student will understand, perceive and master the knowledge. Thus the reusability and pedagogic efficiency are contradictory properties.

Within the context of this problem, we still believe that the LO context should not be rejected on the seeking to reduce LO granularity, and it is necessary to look for new ways of increasing the LO reusability. We suggest increasing the reusability not by rejecting LO context and reducing LOs granularity, but on the contrary, by providing a learning object with a variety of different LOs contexts, so that each user could choose the most appropriate LO. Thus the possibility of reusability in different contexts is retained, meanwhile, LO remains pedagogically rich, valuable and efficient. So, we propose to create generative learning objects (GLO) (the pioneers of the GLO concept are Boyle and his colleges (Boyle, Leeder and Chase 2004; Morales, Leeder and Boyle 2005)) and use feature diagrams (FDs) to its specification in an early GLO development phase. As we see later, in this case granularity does not directly impact reusability.

Specification of a GLO using feature diagrams with reusability in mind

The multidimensional definition of a GLO is given in Štuikys, Brauklytė and Damaševičius (2009). Here we only consider that a GLO elaborates multiple aspects, such as technological, methodological, pedagogical and e-learning. Authors (Štuikys *et al.* 2008) proposed to use feature diagrams in the GLO specification. The proposed model specifies at the high abstraction level (i.e. in the

human readable form) the following aspects of GLO: scope, commonality and variability; essential features of the topic, their relationships and constraints. For a wider feature diagrams’ adaptation, grounding and elements of application in GLO specification refer to article (Štuikys *et al.* 2008). In this article we only recall that variability means different variant of a LO. Variability is influential to granularity, aggregation of LOs and reusability, because technology enables us to create the content on a variety of versions. Adaptations or personalization of materials are common reuse activities. If adaptation will be done automatically, we have a powerful generative reuse. GLOs are an example of such reuse (see next section for more details).

To illustrate GLO specification with feature diagrams, we have selected a simple and well known topic – Boolean algebra. This topic perfectly suits for the GLO development, as it is used in different study subjects (for example, computer architecture, digital electronics, logics, computer science, etc.). Such a wide scope of application of Boolean algebra instantly ensures the necessity and possibilities of reusability. Naturally, each course will have its “own” context. Having reviewed several courses, where Boolean functions are applied, we have distinguished between the following main parameters of variability:

- *target-audience* (beginners or advanced);
- *different functions*;
- *function notation* (different courses use a different function notation);
- *number of expression length* (the number can vary from 2 to (usually) 5, except for the function NOT);
- *graphical visualization of functions*.

We can easily specify the aforementioned variability, commonality and some constraints of LO “Boolean algebra” by the feature diagram (Fig. 1).

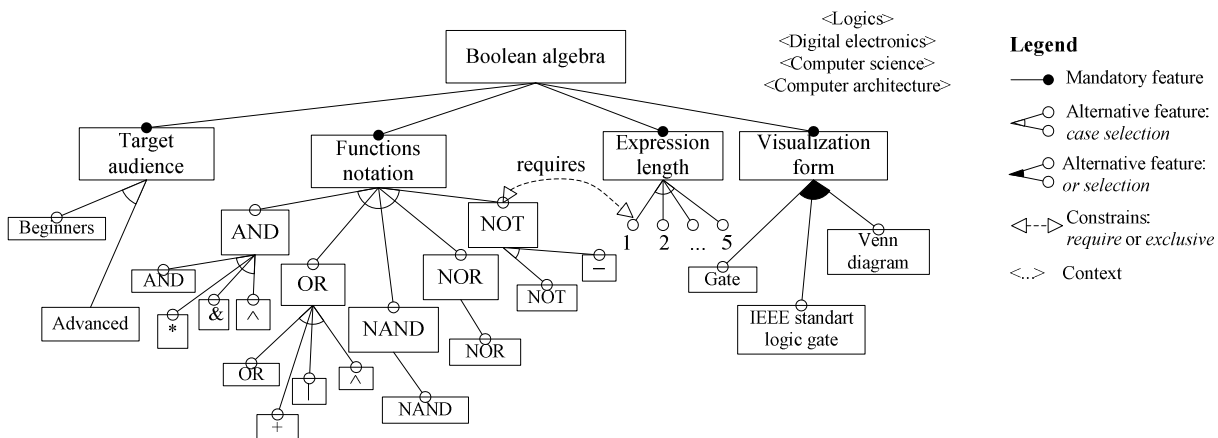


Figure 1. Feature-based model of GLO “Boolean algebra”

From the Fig. 1, we see that the selected area has a high degree of variability, because in different context a different notation is used, Boolean functions require different visualization and etc. For the sake of simplicity in the figure we represented only one constraint between two features, i.e., function NOT has only one input. But there may be others constraints too. For example, functions AND, OR, NAND, NOR requires xor

relationship with feature “Number of entries=1”. So, according to Fig. 1 we can evaluate GLO reusability degree and granularity prior to its implementation, as reusability depends on differences and similarities that can be detected and projected across GLO.

Specifying the variability of GLO in the early phase of the LO development, we increase the potential of reusability from the very beginning of LO development,

i.e. from the very beginning of the LO life-cycle it is developed so as to be reused. Obviously, when seeking to develop GLO, the programmer has to be very well acquainted with the specified field.

The need for adaptation LOs specification by the feature diagrams not only increases the possibility of reusability but also enables to foresee the learning scenarios where LOs may be applied. If LO may be used in 10 different contexts, it means its reusability is 10 times higher than that of such an LO, which can be used just in one specific context (Sicilia and García 2003). In addition, the realization of variability using specific technologies (e.g. patterns or meta-programming technologies) leads to the creation of GLOs, which enable users to adapt LOs to a specific situation or individual needs without changing the code.

In summary, one can conceive that features that are represented by leaves of the three (see Fig. 1) are the lowest level granules of LOs which are specified at a higher abstraction level.

Implementation of GLO

We have selected meta-programming as a generative technology for the implementation of a GLO. Here we speak about the heterogeneous meta-programming techniques, which use two different languages in the same specification: a meta-language for representing higher-level manipulations and domain (or target) language for representing LOs instances. We have selected PROMOL (Štuikys, Damaševičius and Ziberkas 2002) as a meta-language and HTML/Java Script as a domain language for representing LOs.

As GLO is an executable specification it has a well established structure (Fig. 2). A structural model consists of two basic units: meta-data (also called meta-interface) and meta-body. Meta-interface serves for the representation of variability parameters at a higher abstraction level and meta-body – for coding of the commonality-variability relationship at a lower-level.

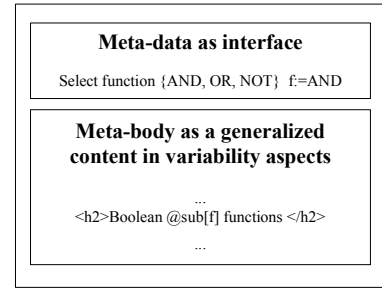


Figure 2. GLO model

Meta-interface allows an educator/teacher or a student to select GLO parameters and to create LO instances according to the purpose.

According to Fig. 1, the values of variability parameters are described in the GLO meta-interface (Fig. 3). The user can select a learning material (i.e., a LO) of different complexity (for beginner or advanced learner), select a desirable function with a preferred notation, select a length of expression in the demonstration example and select at least one visualisation form of a function. On the right hand side of Fig. 3, the default parameters are presented, i.e. in case a GLO user does not select any parameters, the LO will be generated with the parameters provided on the right hand side. Different combinations of selected values can lead to 348 different LO instances generated from this single GLO (for more details see next section). So, LOs instances created by others from single GLO are reused and re-purposed in generating new content therefore there is a considerable reduction in the time and effort taken to produce the new content. This leads to a sharp reduction in the cost to produce new instructional materials, compared to developing the content from scratch. The reused content may even be of a higher quality than if developed from scratch.

\$		
"Select function"	{AND, OR, NOT, NAND, NOR}	func:=AND;
"Select target audience"	{beginner, advanced}	level:=beginner;
"Enter the length of expression"	{1..5}	length:=3;
"Select functions visualization"	{gates, IEEE standart logic gate, venn-diagram}	rep:=table;
[func eq {AND}] "Select symbolic visualization of AND function"	{AND, *, &, ^}	rep_Nor:=nor;
[func eq {OR}] "Select symbolic visualization of OR function"	{OR, +, , v}	rep_Nand:=nand;
[func eq {NOT}] "Select symbolic visualization of Not function"	{NOT, -}	rep_Nand:=nand;
[func eq {NOR}] "Select symbolic visualization of NOR function"	{nor }	rep_Nor:=nor;
[func eq {NAND}] "Select symbolic visualization of NAND function"	{nand}	rep_Nand:=nand;
\$		

Figure 3. Meta-interface of GLO “Boolean algebra”

The meta-body of the GLO is hidden from the end-user (because the technological details of meta-programming are important only for a GLO developer/programmer). The example of generated AND function with set of all meta-parameters with one value for each meta-parameter (function:=AND,

level:=beginner, length:=3, rep:=gates, rep_AND:=AND) is presented in Figure 4.

In general, a meta-program (i.e., meta-interface plus meta-body) is the specification that is a set of weaved LO instances having the same or similar granularity level.

Boolean Algebra

Boolean algebra is a system of algebra (named after the mathematician who studied it, George Boole) based on only two numbers, 0 and 1, commonly thought of as "false" and "true". There are three basic arithmetic operators in Boolean algebra: NOT, AND, OR.

Short description of AND function:

Logical conjunction (usual symbol **AND**) is a logical operation that results in a value of *true* if all of its operands are *true*, otherwise a value of *false*.

Function AND representation:

By truth table:

The truth table of **A AND B** (also written as **A & B** or **A*B**) is as follows:

A	B	A AND B
FALSE	FALSE	FALSE
FALSE	TRUE	FALSE
TRUE	FALSE	FALSE
TRUE	TRUE	TRUE

By gate

The shape-specific logic gate symbol for the AND operation is shown in figure.

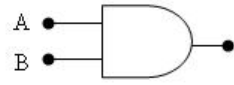


Figure 1. AND logic gate.

Simple demonstration:

Evaluate

true AND true AND true =

Figure 4. Screen shot of LO instances according to selected parameters

Figure 4 presents a model of a derivative LO derived from the GLO. A generated LO instance introduces a student with the AND function basics and represents it in the truth table and gate. As far as only the beginner level was selected (level:=beginner), the learning object presents only a short description of the function as well as the main principles and representation. At the end the learner is given a simple demonstrative problem: a student has to determine an appropriate value (true or false) for the expression of a selected length. To check the answer, the student may click the button "Evaluate". Thus, the student may assess his/her knowledge if he/she understood the selected function correctly. On request, the learner may select another LO instance (derived from GLO) and proceed with the learning of another function. A set of such instances enables to specify a learning scenario or pre-specify routes in the formal graph-based model, as it will be explained in the next section.

Identification of granularity of LO instances derived from GLO

Several LOs should be aggregated in order to construct a learning scenario. In our assumption, graphs are a quite good visual tool for learning modelling in GLO context. Fig. 5 presents several possible cases of LO instances aggregation (also we can call as learning scenarios) based on the elaboration theory, which assumes that learning should start from elementary examples and then proceed with the more complicated ones.

For the sake of simplicity, Fig. 5 presents only 8 LOs; however, Table 2 gives a detailed explanation and presents how many different learning object instances may be generated. Therefore, first of all the learner has to understand the basic principles of Boolean algebra (i.e. to start from the beginning level selecting one of the main functions AND, OR or NOT), then, he/she may either finish the learning process or get acquainted with the modifications of the main functions (NAND, NOR functions), and finally he/she may proceed with the advanced level, which analyses algebraic laws, reductions, Boolean relations and so on.

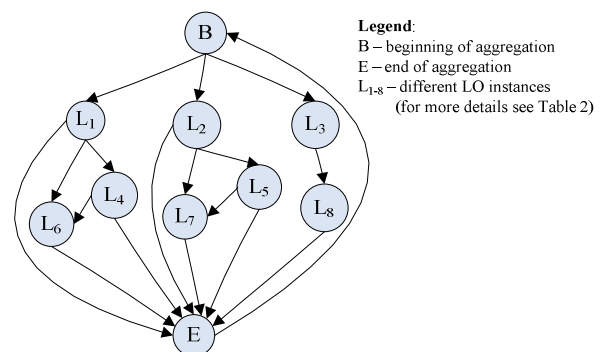


Figure 5. Graph-based model to describe aggregation and granularity of LO instances

The number of the LOs used, the ways they have to be linked and for what purpose are defined by the learning objective, pedagogic methodology and

instructional design theory. We will not analyse this issue in a greater detail because the aim of this paper is the determination and evaluation of the granularity level. In

this case, Fig. 5 will be helpful seeking to evaluate granularity of LO instances derived from GLO.

Table 2. LO instances derived from GLO explanation

des in graph	Number of instances	Explanation
L ₁	L ₁ =1·4·3·4=48 (L ₁₋₃₆ inst.)	lects AND function for beginners, desirable notation and visualization
L ₂	L ₁ =1·4·3·4=48 (L ₄₉₋₉₆ inst.)	lects OR function for beginners, desirable notation and visualization
L ₃	L ₁ =1·1·3·2=6 (L ₉₇₋₁₀₂ inst.)	lects NOT function for beginners, desirable notation and visualization
L ₄	L ₁ =1·4·3·3=36 (L ₁₀₃₋₁₃₈ inst.)	lects NAND function for beginners, desirable notation and visualization
L ₅	L ₁ =1·4·3·3=36 (L ₁₃₉₋₁₇₄ inst.)	lects NOR function for beginners, desirable notation and visualization
L ₆	L ₁ =1·4·3·4+1·4·3·3=84 (L ₁₇₅₋₂₅₈ inst.)	lects AND or NAND function (depends on which branch he/she comes from) advanced persons, desirable notation and visualization
L ₇	L ₁ =1·4·3·4+1·4·3·3=84 (L ₂₅₉₋₂₄₂ inst.)	lects OR or NOR function (depends on which branch he/she comes from) for ed persons, desirable notation and visualization
L ₈	L ₁ =1·1·3·2=6 (L ₂₄₃₋₂₄₈ inst.)	lects NOT function, advanced level, desirable notation and visualization

We would like to mention that the smallest granularity item does not have to be relative to the file size or learning time. We tend to relate the smallest granularity item with one concept or theme (for example, with one Boolean function). As it was mentioned in the performed analysis, we will assume that there are three aggregation levels or the learning objects may acquire three different granularity degrees (according to the LOM standard, aggregation level is as the functional granularity of a LO). So, we distinguish three levels in the GLO context:

- *First aggregation level:* LO instances' with the lowest granularity degree, i.e. one concrete LO instance derived from the GLO. For example, L₁ or L₂ or L₃.
- *Second aggregation level:* LO instances with the middle granularity degree, i.e. one route or sequence (aggregated at least 2 instances) in the graph. For example, B-L₁-L₆-E or B-L₂-L₅-L₇-E.
- *Third aggregation level:* LO instances' with the highest granularity degree, i.e. at least two LO instances' sequences in a composed graph. For example, B-L₁-L₆-E-B-L₂-L₇-E-B-L₃-L₈-E.

We should emphasize that in this case (GLO context) granularity degree does not restrict LO reusability, as the LO adaptation to the individual needs of the learners is ensured by the GLO which enables to select the required parameters from the meta-interface. However, we must know how to evaluate the GLO granularity degree because while describing the GLO by meta-data (according to LOM standard) it is necessary to indicate the aggregation level.

Summarizing the whole discussion, first of all we may draw a conclusion that the GLO granularity does not restrict the possibilities of reusability and we don't need to reduce LO granularity or to refuse context to support reusability. In addition, the offered formal graph-based model not only enables the modelling of learning scenarios but also allows the evaluation of the LO

granularity degree (aggregation level of compound instances derived from GLO), which is essential by describing GLO with meta-data.

Conclusions

The proposed model for the identification of granularity is a graph-based model in which nodes represent derivative LO instances derived from the given GLO and arcs (directed branches) represent a logical sequence among the instances for their interpreting within the learning/teaching process. The separate LO instances compose the first aggregation level. The second aggregation level is a composition of instances (a route from the beginning to the end). The third aggregation level is a few different routes from the beginning to the end in the model. How many different routes should be selected in the third level depends on the objectives, initial granularity of LOs and context of use. The model enables to evaluate the reusability extent and compare LOs at a high abstraction level.

Further research is intended to expand and incorporate the proposed model to deal with a more general problem such as aggregation/sequencing of LO instances.

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GENERATYVINIŲ MOKYMOSI OBJEKTŲ GRANULIACIJOS ANALIZĖ PAKARTOTINIAM PANAUDOJIMUI PAREMTI

S a n t r a u k a

Mokymosi objektas (MO) yra neatsiejamas e-mokymosi srities elementas. Susidomėjimas šia sritimi auga, nors MO sąvoka el. mokymesi jau žinoma 15 metų ir yra pakankamai plačiai taikoma. Šioje srityje dirba tiek mokslininkai, tiek stambiausios korporacijos, bet MO srityje lieka daug neišspręstų problemų. Viena iš pagrindinių – MO pakartotinis panaudojimas, kuris glaudžiai siejasi su MO granuliacija. Mokslinėje literatūroje analizuojama, kaip tinkamai parinkti MO granuliacijos laipsnį neprarandant MO pakartotinio panaudojimo efektyvumo. Juk MO pakartotinis panaudojimas yra pagrindinė priežastis dėl kurios siekiama MO integruoti į e-mokymosi sritį. Efektyviai adaptuojant (pakartotinai panaudojant) sukurtą mokymosi objektą, sutaupoma daug laiko, resursų, išlaidų, gerėja MO kokybė ir t.t.

Dauguma tyrinėtojų siūlo tiesiog mažinti MO iki mažiausio granuliacijos laipsnio, kurį vieni tyrėjai sieja su laiku, kiti – su viena tema ar net sąvoka. Iš tiesų juk kuo MO bus mažesnis, nesusietas su konkrečiu kontekstu (pvz., paveikslukas ar trumputė iliustracinė animacija), tuo įvairesniuose kontekstuose galėsime jį pakartotinai panaudoti. Tačiau smulkinant MO iki atskirų elementų ir šalinant kontekstą, prarandama MO pedagoginė vertė, t.y. tokie MO tampa nebe efektyvūs besimokančiojo atžvilgiu. Taigi šios problemos sprendimui siūloma kurti generatyvinius mokymosi objektus (GMO) apjungiant dvi technologijas: požymių diagramas GMO specifikacijai ankstyvojoje kūrimo fazėje bei meta-programavimą GMO realizacijos metu. Požymių diagramos remiasi variantiškumu, panašumų bei apimties analize ir leidžia užtikrinti pakartotinio panaudojimo galimybių įvertinimą ankstyvojoje GMO kūrimo stadijoje. Tuo tarpu meta-programavimas užtikrina generatyvinį pakartotinį panaudojimą, t.y. MO adaptacija arba pritaikymas prie individualių vartotojų poreikių atliekamas automatiškai, vartotojui užtenka iš vartotojo

sąsajos pasirinkti atitinkamus parametrus, pagal kuriuos sukuriamas personalizuotas MO. Taip pat reiktų paminėti, jog požymių diagramos leidžia įvertinti MO granuliacijos laipsnį aukštesniame abstrakcijos lygmenyje, t.y. požymiai, esantys pateiktoje medžio struktūros lapuose gali būti interpretuojami kaip MO, turintys mažiausią granuliacijos laipsnį.

Šiame straipsnyje pateiktas konkretus GMO „Bulio algebra“ projektavimas bei kūrimas naudojant aukščiau išvardintas technologijas. Kadangi GMO apima įvairiapusę informaciją, specifikacijoje numatytus kontekstus, tokiu būdu GMO yra pedagogiškai efektyvus (nes nereikia atsakyti konteksto siekiant užtikrinti pakartotinį panaudojimą) bei jo granuliacijos laipsnis visiškai neriboja pakartotinio panaudojimo galimybių. Vadinas, galime daryti išvadą, jog GMO automatiškai išsprendžia dalį MO problemų, nes GMO yra vertingas pedagoginėje plotmėje, o jo granuliacija neriboja pakartotinio panaudojimo galimybių (t.y. mums nereikia dirbtinai smulkinti GMO siekiant jį dar kartelį panaudoti kitame kontekste).

Tačiau GMO granuliacijos laipsnį būtina mokėti įvertinti, nes aprašant GMO (ar iš jo sugeneruotus MO egzempliorius) metaduomenimis reikalaujama nurodyti agregacijos lygmenį. Šiai problemai spręsti siūloma naudoti formalų grafais pagrįstą

modelį, kurio viršūnės vaizduoja MO egzempliorius, gautus iš GMO, o lankai – loginę seką tarp sugeneruotų MO. Nors literatūroje naudojamas skirtingas agregacijos lygmenų skaičius, tačiau pagal atliktą standartų, modelių bei atskirų mokslininkų siūlomą granuliacijos įvertinimą, nustatyta, jog visus kitų autorių minėtus MO granuliacijos laipsnius (arba agregacijos lygmenis) galima suskirstyti į tris pagrindinius lygmenis. Remiantis šia prielaida, MO egzempliorių granuliacija taip pat įvertinta pagal tris lygmenis. Atskiri MO egzemplioriai turi mažiausią granuliacijos laipsnį (t.y. sudaro pirmą agregacijos lygmenį). Grafo kelias (sudarytas iš mažiausiai dviejų MO egzempliorių) nuo agregacijos pradžios iki pabaigos (arba vienas kelias grafe) sudaro antrą granuliacijos lygmenį. O trečias granuliacijos lygmuo apima keletą grafo kelių, kai besimokantysis išmokęs vieną grafo kelią, susigeneruoja iš naujo (arba pasiima jau sugeneruotą) kitą grafo kelią. Tokiu būdu pasiūlytas grafais pagrįstas modelis ne tik leidžia įvertinti granuliacijos laipsnį, bet tuo pačiu gali prisidėti prie skirtingų mokymosi scenarijų modeliavimo aukštesniame abstrakcijos lygmenyje.

PAGRINDINIAI ŽODŽIAI: mokymosi objektai, generatyviniai mokymosi objektai, pakartotinis panaudojimas, granuliacija.

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